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HUMAN DIMENSIONS IN FUTURE BATTLE COMMAND SYSTEMS: A WOKSHOP REPORT

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11. SUPPLEMENTARY NOTES

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13. ABSTRACT (Maximum 200 words)

This is an event report on a workshop on human dimensions in future battle command systems with the objectives to: inform the relevance of human dimensions in future modular forces with network-enabled Battle Command System (BCS); identify design and analysis requirements for human-technology collaborative work systems for future network-enabled BCS; inform requirements for commander-centric doctrine and training developments. The workshop used subject matter experts. The workshop recommendations do not advocate any standard or must follow "issues." It was noted that the human dimensions will have to transcend the constructivist and physique concepts to mentalist and cognitivist. The commander was viewed as an intelligence leader who must be responsive to **C**hanges; **A**dapt to those changes; **L**earn from situation outcomes; and **L**ead by example. This **CALL** model defines the commander abstractly when in contact with the changing and often unknown and chaotic battle environments. Requirements for studying higher order cognitive skills (HOCS) were elucidated through eleven identified insights. It was observed that the human dimension issues will deal with t increasing cognitive requirements that must be studied through complimentary disciplines of situation awareness, sensemaking, and situation understanding. Issues to frame HOCS were identified along knowledge management, decision support systems, sensory attention, and neural-level information processing with bias towards possible network capability and occasions of degradation.

14. SUBJECT TERMS **Awareness, Battle Command System, Human Dimension, Higher Order Cognitive Skills, Visualization and Cognition, Sensory Attention**			**15. NUMBER OF PAGES** **16. PRICE CODE**
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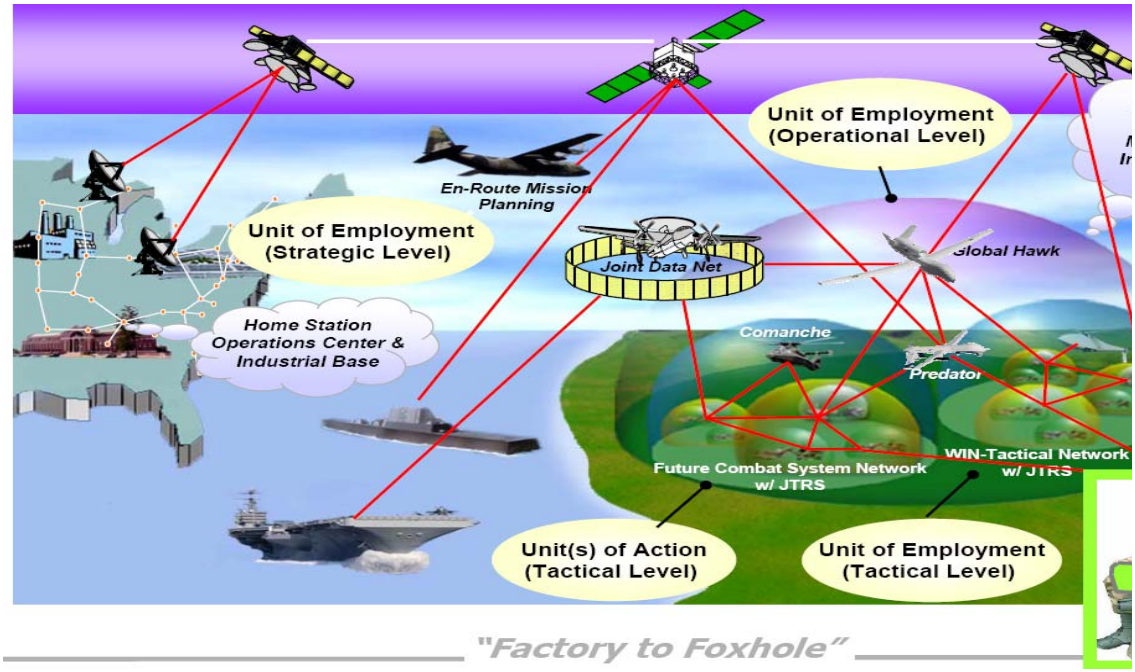

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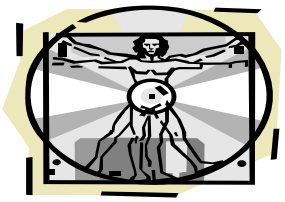

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Acknowledgement, Objective, Disclaimer, and Contents

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Disclaimer:

The opinions presented in this report are not those of Army Research Office (ARO) and are solely those of the author(s).

Objective: To provide an event report on a workshop on human dimensions in future battle command systems. The realization are:

- Inform the relevance of human dimensions in future modular forces with network-enabled Battle Command System (BCS).
- Identify design and analysis requirements for human-technology collaborative work systems for future network-enabled BCS.
- Inform requirements for commander-centric doctrine and training developments in all phases of command organizations, including unified command BCS.

Workshop Overview

What: The Art of Command Workshop explored human dimensions in the future Battle Command Systems (BCS) with bias towards higher order cognitive (HOC) requirements needed for situational understanding and decision superiority.

When: April 3-4, 2001.

Where: Sheraton Norfolk Waterside, VA, USA.

Why: To inform emerging operational doctrine and human dimension issues in future battle command concept development.

Who: Participants included subject matter experts (SMEs) from US Army Combined Arms Center-Battle Command Battle Laboratory (CAC-BCBL), Army Capabilities Integration Center (ACIC), Defense Advanced Research Projects Agency (DARPA), Human Research and Engineering Directorate (HRED) of the Army Research Laboratory (ARL), and North Atlantic Treaty Organization (NATO). Below are the pictures of some of the participants.

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8th Annual Symposium on Human Interaction with Complex Systems and 2nd Sensemaking of Complex Information
April 3-4, 2008
Sheraton Norfolk Waterside Hotel, Norfolk, VA, USA

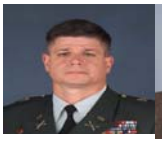
Special Panel on The Art of Battle Command


LTG (Retired) Keller


BG Berk NATO


COL Dunn BCBL

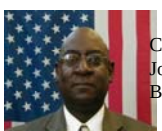

COL Surdu, DARPA

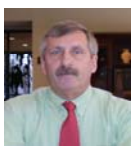

COL Bullimore ACIC


Dr. Bassan, HRED/ARL


COL. (Rtd). J. Connelly


COL (Rtd.) . Murphy


COL (Rtd). Johnson, BCBL


Mr. Cassella

Workshop Execution (April 3-4, 2008)

Day 1: Human Cognitive Dimensions (Lead: COL (Rtd) Calvin Johnson, BCBL-Leavenworth).

- Arts of battle command and human dimension requirements Battlefield visualization and cognition.
- A framework for emerging work system for future battle command systems

Day 2: Coping with Information Complexity of the Battle Space (lead: LTG (Rtd.) Richard Keller).

- Complexity nature of command organizations/ Case studies.
- Differentiating social network and technology-enabled network-centric command and control (C2).
- Human dimensions, higher order cognition, and training requirements for the commander.

Purpose

1. The purpose of this workshop was to abstract information from experts on human cognitive dimensions in the future battle command systems. The basic question for discourse was:
   What roles and capabilities are required to enable the commander to function well in technology-enabled battle command systems?

2. The workshop laid a fundamental framework to identifying the requirements for leadership and training needs for future Battle Command Systems (BCSs).

3. Among the important discussions were knowledge requirements for the art of 2024 battle command. Both the definitions of "ART" and "SCIENCE" aspects of BCS were argued. However, the premise of the discussions was on the Art of Battle Command. The science aspect *remains a central role, but not a primarily discussion for the panel.*

   The overarching fundamental questions (FQ) were derived from each insight:

   a. What are the synergistic characteristics that make BCS human-centric? (Insight-1).
   b. What are the features that make BCS a complex adaptive system? (Insight-2).
   c. What are the major enabling supports of BCS to the commanders, battle staffs and the field soldiers? (Insight-3).
   d. What are the characteristics of the commander in the future the BCS? (Insight -4).
   e. What are the features of the commander's decision tools in BCS? (Insight-5).
   f. What are the characteristics of command leadership in the future BCS? (Insight-6).
   g. In the information-dominated operational environment, have we adequately prepared our current and emerging battle commanders to be cognitively ready? (Insight-7).
   h. What technology characteristics are required to produce a true collaborative, joint human-technology BCS? (Insight-8).
   i. What are the components of human dimensions in technology-enabled Joint Battle Command systems? (Insight-9).
   j. What is the nature of work system in the future Battle Command Systems? (Insight-10).
   k. If most of the commander's task will be cognitive under BCS, what is the nature and level of cognitive skills desired to enable the commanders to cope with information technology capabilities? (Insight-11).

Premise

The workshop had two moderators: one for human cognitive dimensions for BCS (first day) and one for coping with BCS information complexity (second day). The workshop used a seminar style, dialog, and audience participative (question-answering) approach.

The moderator introduced the Panel participants.

The Chair calls the session to order and give 5-10 minutes brief of the panel.

The Chair calls on the participants to present their viewpoints on the subject matter (The Panel Chair will budget time).

Step 3 is repeated until all participants have presented.

The Chair calls for questions from the audience.

The Chair summarizes the important observations.

The Session comes to a close.

Executive Summary

According to General Frederick M. Franks, Jr., battle command means seeing what is now, visualizing the future state or what needs to be done to accomplish the mission and then knowing how to get your organization from one state to the other at least cost against a given enemy on a given piece of terrain. The primary components of battle command that depend directly on the commander's intuition are decision making, visualizing, concept formulation and battlefield awareness--selecting the critical time and place to act, and knowing how and when to make adjustments during the fight. Coupled with technology capabilities, the commander's tasks are expected to shift towards more requirements of meta-cognitive skills which have to be enabled by seamless management of sensory information and modalities of processing the information. In the technology-enabled BCS, both the battlefield technology sensors and the human sensory systems interact, reducing the commander's decision time and information space equal to only the speed in which the battle sensors are processing that information. While the commander's attention and memory capabilities are relatively static, it is argued that the cognitive ability can be amplified by taking opportunity of how humans process information, most particularly, the understanding of information processing at the neural levels.

Human dimensions in the battlefield were discussed even though they are not new. However, in the future BCS, the human dimensions will have to transcend our parochial constructivist and physique concepts to mentalist and cognitivist approach. Here, the commander must manage multifaceted human variables. The commander is then an intelligence leader who must be responsive to **C**hanges; **A**dapt to those changes; **L**earn from situation outcomes; and **L**ead prudently by example. This **CALL** model defines the commander abstractly when in contact with the changing and often unknown and chaotic battle environments. The commander's dimension also has a side for dealing and coping with psychological innuendos such as battlefield fatigue, fear, motivation, morale, cultural diversity and so on.

In view of this evolving battle system characteristics, the commanders are required (and must be trained) to demonstrate their cognitive expertise and to make decisions in complex and/or chaotic scenarios without having to go through tedious analytic reasoning process. In general, however, this requirement has been a norm rather than an exception. This is the reason the current military doctrines and standard operation procedures emphasize the training of cognitive skills (FM3-07).

Particular types of knowledge structures are needed for proficient problem-solving and decision-making by the military commanders. Much of this knowledge is conceptual in nature, as opposed to operational or procedural. The presence of conceptual elements in the knowledge structures is the key to having a "deeper understanding" of the problem space. Particular types of

cognitive processes are required for the acquisition of conceptual knowledge and the construction of useful knowledge structures.

The epistemological and ontological issues of human dimensions in the future BCS are nascent and not well understood, especially when premised from higher order cognition framework. The purpose of this workshop was to seek ways to address these issues. Two issues were addressed during the two one half-day workshops: Human Cognitive Dimensions and Coping with Information Complexity of the Battle Space.

The human cognitive dimension issues dealt with the increasing cognitive requirements in lieu of too much information technology in the battlefield which is often the culprit of cognitive (or mental) workload. Particularly, requirements for studying higher order cognitive skills (HOCS) were elucidated. COL (retired) Calvin Johnson led the panel with a focus towards visualization and cognition skills, including the defining moments when the commander has to use the available cognitive tools, skills, and methods. The second panel dealt with coping with information complexity of the battle space, and was a synergistic continuation of the requirements for HOCS. LTG (retired) Richard Keller led the discussion with case studies reminiscent of actual BCS operations. It was observed that the military environment is more than a battlefield; it's a network of interrelated political, military, economic, social, informational, and infrastructure systems that are beyond a military-only ability to visualize. For these reasons, battle command is both an art and science.

The need for the commander to acquire the ability to map DIME (Diplomatic, Information, Military, and Economic) to PMSEII (Political, Military, Economic, Social, Infrastructure and Information) was discussed with emphasis on the commander's HOCS. The DIME-PMSEII matrix is the mapping of tactical elements to informational values that govern the behavior of conflicts. Throughout the eleven identified insights from the workshop, summaries of each insightful discussion and their observations/recommendations are presented. Each insight has attempted to address the human dimensions, HOCS, and the training requirements.

It must be mentioned that the workshop used subject matter experts consisting of two Army Generals (1 retired, 1 active), and eight Army Colonels (5 retired, 3 active). Collectively, the experts brought to bear a total minimum of 300 years of service. This report has attempted to capture this expert viewpoints and suggestions. However, the workshop recommendations do not advocate any standard or must follow "issues." Rather, the workshop intend is to look into future human cognitive requirements in a future BCS were both the humans and technologies will depend on each other and in which cognition skills will be more dominant, pervasive, and inevitable.

Workshop Insights

The insights gained from the workshop are summarized below. A detailed outcome analysis for each insight is presented in the discussion sections.

Insight 1: A Battle Command System (BCS) is human-centric and technology enabled. The informational elements of a BCS are premised on enhancing the commander's information superiority though seamless situation awareness (SA) and situation understanding (SU). Technology is critical in generating the desired information superiority which must be translated into decision superiority by the commander and the battle staffs.

Insight 2: A BCS is a complex system of interacting technology and human behaviors. These behaviors are interleaved with demanding human endeavors and unpredictable technology glitches. Designers and managers of BCS must be cognizant of system level degradations and occasional increase in cognitive workload of the battle staffs and the commanders.

Insight 3: Battle system awareness (BSA) is a bye-product of BCS. BSA provides ubiquitous system- and individual- level models to enable the battle staffs and commanders understand the battle environments that consist of adversaries, equipment, people, tools, and so on. The interactions of BSA and human behaviors create the ominous needs for sensemaking, situation awareness, and situation understanding.

Insight 4: In the technology-enabled BCS, the commander is considered to be an adaptive knowledge worker. The commander must stay agile, be informed, be responding to changes in information, and be equipped with mobile SU systems through intelligent sensor-enabled SA. The commander must be able to reason from the first principle of self-awareness in a technology degraded SA environment.

Insight 5: The commander and the battle staffs will need intelligent (crystal ball type) decision support systems (DSSs) that can help them to envision, predict, and anticipate future states of a battle space—events, adversaries, inter-agency and intra-agency operators, and so on. Such DSSs must be able to use symbolic information as an input. This can be in the form of graphics, episodic, and echoic waveforms which can be transformed into seamless information coding schemes for display and visualization models as intelligent analysis tools.

Insight 6: Future battle commanders must be ambidextrous leaders. The commanders, at different times and space, must be capable of changing, adapting, learning, and leading a team in battle environments with changing information characteristics and footprints.

Insight 7: Training and education of the future commanders need to be centered on technology pedagogy while emphasizing professional self- and group- developments and experiential training. The training and education courses should be packaged to be rapidly adaptable and portable similar to intelligent ad-hoc network systems. The commanders and the battle staffs must have access to education and training opportunities anywhere, any time by using technology platforms that can integrate and use COT (Commercial Off the Shell Technology).

Insight 8: Technology in the future BCS must be designed to be minimally uninterruptable, rugged, and resilient so as to be protected against enemy attacks and uncertain failures. The technology platform must be scalable, interoperable, reliable, and trustworthy.

Insight 9: Human dimensions in Joint Battle Command (JBC) systems remain problematic. Achieving human network interoperability requires the understanding of socio-cultural cognition, ecological sensemaking, and the ability to reconcile and scale different standard operating procedures (SOP) into a common metric of doctrinal statements. The operational impacts of socio-cultural and human terrain networks, node-to-node commander's intent with mixed and joint command structures will continue to be a limiting factor in successful JBC operations.

Insight 10: The future battle command (BC) work systems should and must be redefined in terms of transformational paradigm shifts in doctrines across all service levels (joint, intra-, lateral, and horizontal) with regard to edge network-centric philosophy. Achieving this will require a new concept of work design known as Intentional Work System (IWS).

Insight 11: Transitioning into an IWS will require an assumption-based cognitive architecture (ACA) that will explore more studies in high order cognitive (HOC) information processing. High order cognition should be able to remind the decision makers of many expectations in evolving situations by combining multi-level memory and attention resources to gain battle system situation understanding in multiple trait and multiple- interleaving levels of system abstractions that include individual cognitive level, organizational or social level, and ecological level, respectively.

2. Prolegomena

2.1. Brief Introduction to Battle Command Systems

Battle Command Definitions:

The battle command concept was developed by General Frederick Franks, Jr. to account for the human dimension of battle. According to Franks, battle command means seeing what is now, visualizing the future state or what needs to be done to accomplish the mission and then knowing how to get your organization from one state to the other at least cost against a given enemy on a given piece of terrain. The primary components of battle command that depend directly on the commander's intuition are decision making, visualizing, concept formulation and battlefield awareness--selecting the critical time and place to act, and knowing how and when to make adjustments during the fight.

Battle command (BC) is the art and science of understanding, visualizing, describing, directing, leading, and assessing forces to impose the commander's will on a hostile, thinking, and adaptive enemy. Battle command applies leadership to translate decisions into actions—by synchronizing forces and warfighting functions in time, space, and purpose—to accomplish missions. [FM 3-0, pg 5-2]

- Emphasizes the central role of the commander in operations; focuses on the art of battle command in an increasingly complex security environment.
- Ties together battle command and operational art, providing a model for the creative application of the experience, knowledge, and intuition of the commander in full spectrum operations.

Battle command is the art and science of applying leadership and decision-making to achieve mission success. Battle command applies leadership to translate decisions into actions, by synchronizing forces and warfighting functions in time, space, and purpose, to accomplish the mission. The battle command construct will provide enhanced situation awareness (SA) to both the individual and group of service personnel; at the command level, an enhanced SA is will lead to the commander's decision superiority. Few cursory descriptions of BC are:

1. FM44-100, US Army Air Defense Operation 15, June 1995: Army's Stand-To (http://www4.army.mil/news/standto.html Tue, January 23, 2007: Battle Command is the art and science of applying leadership and decision making to achieve mission success.

2. LTG. William S. Wallace (Military Review, May-June, 2005): In the Battle Command concept, commanders use a personal decision-making process that incorporates visualizing the

operation, describing the operation in terms of intent and guidance, and then directing actions within that intent.

3. Army Transformation Road Map, 2003: Battle command is the art of battle decision making, and leading and motivating soldiers and their organizations into action to accomplish missions at least cost to soldiers. Battle command includes visualizing the current and desired future states of friendly and enemy forces and then deciding how to get from one to the other at least cost.

4. FM 7-30, Chapter 3: Battle command involves a continuous process of estimates, decisions, assigning tasks and missions, executing tasks and missions, and acquiring feedback. This process includes deriving missions, formulating concepts and successfully communicating the commander's intent. Courses of action are developed and analyzed.

Essentially, the functional concept of BC is partly enabled by technology with the human in-the-loop and partly operational in the level of autonomy with no human involvement. In both cases, information in BCS has to be reduced to the level of human understanding through display and visualization techniques. Therefore, human dimensions in such a system must be well represented at important levels of human endeavors: cognitively, physiologically, psychologically, socially, and biologically (e.g., neural information processing). These dimensions can best be described anecdotally and metaphorically as:

- Battle command is a human-centric organization.
- If people are not the center of war operation, there is no center at all (General Wallace).
- There are no bad regiments; but bad colonels (Napoleon).

2.2 The Art of Battle Command

The art of battle command embodies two key components: the ability to decide, or military decision-making, and the ability to lead --leadership. Decision-making involves knowing when, and what to decide. Operational decisions involve anticipating events and comprehending the consequences of decisions in battle. The commander must understand the higher commander's intent. He must identify possible enemy courses of action, visualize the desired end state, and have a concept of his own operations which h considering current and future operations concurrently. Once this is done, the commander then must dearly articulate his intent and communicate clear, concise orders to subordinates for execution. Leadership, on the other hand, involves the personal side of command and develops according to the leader's

> Battle command applies the leadership element of combat power. It is principally an art that employs skills developed by professional study, constant practice, and considered judgment. Commanders, assisted by the staff, visualize the operation, describe it in terms of intent and guidance, and direct the actions of subordinates within their intent. Commanders direct operations in terms of the battlefield operating systems **(BOS:Chapter 5, p.1); Through the art of command, commanders apply their values, attributes, skills, and actions to lead and motivate their soldiers and units (page 2).**

individual style. It provides motivation and a sense of purpose for the unit.

Some military doctrines describe BC as an art as follows:

- *Art* is the application of creative imagination by commanders—supported by their skills, knowledge and experience—to design strategies, campaigns, and operations and organize and employ military forces [FM 3-0].
- *Art* integrates ends, ways and means [FM 3-0].
- *Art* reflects an intuitive understanding of the operational environment and the approach necessary to establish the conditions for success [FM 3-0].
- *Art* requires commanders to draw on experience, knowledge, education, intellect, intuition, and creativity [FM 3-0].
- *Art*, as opposed to science, requires expert performance of a specific skill using *intuitive faculties* that cannot be solely learned by study or education [FM 6-0].
- Principally, battle command is an art that employs skills developed by professional study, constant practice, and considered judgment [FM3-90.2, Chapter 3].
- Command is the authority a commander in military service lawfully exercises over subordinates by virtue of rank and assignment. Leaders possessing command authority strive to use it with firmness, care, and skill. Command remains a very personal function. As such, it is more an art than a science, although it exhibits characteristics of both [FM3.0, Chapter 5].
- It as a combat function; battle command is the art of battle decision making, leading, motivating soldiers and units into action. It includes visualizing your current and future state [FM 100-5].
- Battle command will remain predominantly an art form incorporating elements of scientific analysis, control, and direction wherein the experienced commander develops a seemingly intuitive feel guiding his decisions [Army Science & Master Plan (ASTMP 1997].

3. Battle Command System Architecture

3.1 Background

Hammes[1] has termed fourth-generation warfare—one where the adversary is not known, battlefields are defined by complex interactions of human and technologies; orchestrated needs to turn information into adaptive decision process; there is more demand for the commanders, battle staffs, and troops to be agile, adapt, and change along the axes of battlefield information; and more than ever, the persistent needs for situation awareness and sensemaking of the battlefield information space. Battle command system architecture (BCSA) represents a system engineering approach of representing how the technology and human elements interact to provide the service personnel the required information, in the right format, at the time needed, and for the intended purpose.

The BCSA and the battlefield environment provide a challenging environment to the human endeavor because of many properties:

Complex and Adaptive:

- Causality is complex and networked.
- Emerging behaviors are unpredictable, but some order may be observed.
- Cause-effect linkages are known only in retrospect, and not repeatable.
- If recurrent patterns and trends occur, they use different rules.
- Actors have shifting or changing roles.
- Behavior of the system is understood through "trial and discovery" process for specific aspects of a situation.
- The behaviors of interacting agents are responsible for complexity: the system must itself adapt as its constituents members change (in strategies, tactics, etc): Ashby's Law of Requisite Variety
- Few or many emergence behaviors can arise, in random, or in predictable patterns over history.

[1] COL T. X. Hammes (2004). Hammes, T.X. (2004). 4th-generation warfare. *Armed Forces Journal*.

Chaotic and Unstable:

- Experiences occasional turbulence, pandemonium and chaos due to misaligned energy dissipation such as degradation and failures.
- Cause-effect linkages are not perceivable.
- There is no order in the emerging behaviors; if order exists, it is spatio-temporal and rapid, and difficult to observe and quantify.
- The shaping factors for causes and/or effects are unpredictable.
- Poor leadership, economic disparity, and religious intolerance are likely to lead to the fermentation stage of chaos.
- Despotic, authoritative and undemocratic rules usually bring political instability.
- Most instability can be associated to political, economic, social, military, and infrastructure problems.
- Apart from natural calamities such as earthquake and hurricanes, chaotic systems are of human order; further chaos are created when solving human problems with military solutions.

4. Insights and Discussions

Insight 1: A Battle Command System (BCS) is human-centric and technology enabled. The informational elements of a BCS are premised on enhancing the commander's information superiority through seamless situation awareness (SA) and situation understanding (SU). Technology is critical in generating the desired information superiority which must be translated into decision superiority by the commander and the battle staffs.

<u>Fundamental Question:</u> What are the synergistic characteristics that make BCS human-centric?

Discussion:

- ✓ Battle command system is inherently commander-centric, but technology enabled.
- ✓ The human is poor in analyzing large volumes of data.
- ✓ The human only process through a few alternatives when thinking about solutions.
- ✓ The commanders do not process through all attributes when making a decision.
- ✓ The soldier is the single most important aspect of the combat power of the future.
- ✓ Battle decisions lie solely in the hands of the commander. These include the ability to use technology to fight war.
- ✓ Despite the expected proliferation of technology and unmanned systems, the roles of the soldiers remain the cornerstone for force projection. The commander's role will not change since information generated by technology has to be analyzed for decision making.
- ✓ Soldiers, not equipment, accomplish missions and win wars. In order to achieve revolutionary effectiveness across the full spectrum of conflict, human engineering capabilities will have to receive important since the soldiers have to use technology to accomplish many battlefield operational tasks. Examples include, coping with task complexity, decreased execution times to improve performance while minimizing sensory, cognitive, and physical demands.
- ✓ The commanders manage technology (resources, assets, etc.) and not the other way around.

Observations/ Recommendations:

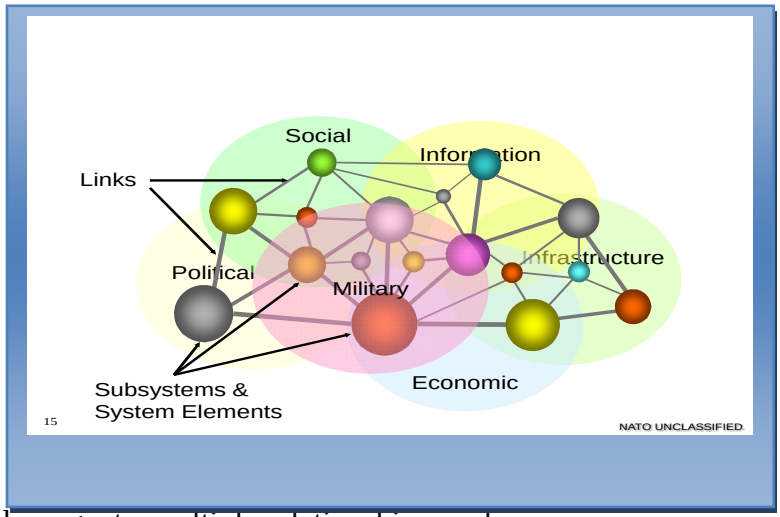
- The commander must be a visionary; should have the means to acquire Level 3 SA (envisioning, anticipating, and predicting future system states) while operating continuously at Level 2 SA (comprehension and situation understanding).
- The commander and the battle staff will require continuous training to establish "perpetual" expertise and experience.
- The commanders in the BCS must be ready for undefined evolving moments of leadership, especially, when technology glitches and the command and control (C2) systems degrade.
- The commander's skill will shift towards a continuum that demands higher order cognitive skill, while retaining the flexibility to delegate, act, and adapt to changes in types of battle field information footprints as well as having the authority to use available and enabled technology to defeat the enemy wills and means.
- The commander must be able to recognize the changing dynamics of organizations and teams as enabled by information technology.
- The commander will need to reconcile the differences and requirements in the traditional human-enabled centralized organizations and technology-enabled decentralized organizations. Both require different C2 elements, but authority still lies with the commander.
- The commanders should also be cognizant of the changing types of risks in technology-enabled BCS;
    - Recognize risks, and accept risks when necessary;
    - Recognize operational and tactical dimensions of war—delineating technology and human roles in different levels of conflicts;
    - Think in a non-symmetrical manner while recognizing the linear dimensions of doctrines at different layers of abstractions: strategic, operational, and tactical.
    - Recognize high stake opportunities, and build energy into battle staff silos.

Insight 2: A BCS is a complex system of interacting technology and human behaviors. These behaviors are interleaved with demanding human endeavors and unpredictable technology glitches. Designers and managers of BCS must be cognizant of system level degradations and occasional increase in cognitive workload of the battle staffs and the commanders.

<u>Fundamental Question:</u> What are the features that make BCS a complex adaptive system?

Discussion:

- ✓ A battle command system (BCS) is a complex adaptive system.
- ✓ There are many sources of complexity in BCS: adversary level complexity that defines the mission scope; design complexity from technology, ecological complexity from terrain and weather, and human level complexity from organizational design.
- ✓ A BCS requires extraneous human endeavors.
- ✓ The fog of war is amplified by the requirements for processing myriads of information generated by technology.
- ✓ Uncertainty, chance, and friction reflect the complexity of operations; their presences are persistent and are different for different contexts or situations.
- ✓ A BCS is a network of people and technology.
- ✓ A human terrain network system is a subset of BCS, created and analyzed from a complex social networked causation. While technology is responsible for information generation and aiding in delivering battlefield effects, the commander should not neglect the human social network:



  - A network with different agendas, agents, multiple relationships, and a constellation of complex friendly-adversary players.
  - A network full of deceptions and hidden information of complex physical and social entities.

- Organizationally, the commander must and should recognize the several layers of interconnectedness and interactions of the social entities, at different dimensions—horizontal, vertical, and possible emerging constellation of information webs.

Observations / Recommendations:

- Insufficient technology exists for reliable support of the interaction gap between technology and humans in the BCS.
- There is limited understanding of the information management issues (accessing, processing, dissemination, presentation) which must be implemented with distributed functionality in network-centric environments.
- There is a gap in providing enterprise level monitoring and control of information in BCSs. This leads to possibilities of poor feedback, increase delayed latency time in decision making, and poor flow (or lack) of information to relevant points of interests.
- Insufficient supporting tools to allow the commanders to focus on decision and execution phases of war, rather than the process.
- Commander tools or technology associates should provide the commanders and battle staffs seamless assistance for understanding battle information so as to guide their actions.
- BCSs are systems that are characterized by both complex interaction and tight coupling of humans and technology, and are confronted by a managerial dilemma when failures of either of human or technology are experienced.
- Several complexity issues to be addressed include, but are not limited to:
  - Scalability
  - Nodal interoperability
  - Reconciling technical design and operational requirements and their field efficacy vs. design face value validation
  - Real-time package exchange scheduling in spatiotemporal dimensions
  - Synchronizing user cognitive dimensions and system-level functions
  - Multilevel, multi-attribute, multiple objective optimization problems.
  - Managing resource allocation and reallocation problems in dynamic situations.
- Identify and formulate ontology frameworks for consistent data usage and information management across the network of BC enterprise systems—to carter for the needs of all services and their commands.
- Consistencies in data structures and representation should be transported digitally across network nodes with acceptable loss of meaning and information contents.

Insight 3: Battle System Awareness (BSA) is a product of BCS. BSA provides ubiquitous system- and individual- level models to enable the battle staffs and commanders understand battle environments that consist of adversaries, equipment, people, tools, and so on. The interactions of BSA and human behaviors create the ominous needs for sensemaking, situation awareness, and situation understanding.

Fundamental Question: What are the major enabling supports of BCS to the commanders, battle staffs and the field soldiers?

Discussions

- ✓ Awareness is a human construct; it is both intrinsic and extrinsic.
- ✓ Battle system awareness (BSA) is the creation, dissemination, and use of information in graphical, pictorial, and symbolic forms.
- ✓ BSA is a functional concept that ties information in the battle space so that the battle staffs can understand the environment in which they operate.
- ✓ Awareness is the ability to gain "insight" and anticipate a situation and make assessments relevant to one's intent and the environment.
- ✓ Human mind (and its thought contents) is the center of gravity (CoG) of human awareness; the sensory information from the surround helps to direct the attention to selective awareness required for a context.
- ✓ At any given moment, self awareness is important to the soldier; self awareness is the understanding of what is important to the individual soldier, knowing what to do, knowing feeling, and knowing how to execute tasks without directives; the self-awareness is connected to emotions, thoughts, and actions.
- ✓ Team or group situation awareness is more than a construct; it is glue that binds the battle staffs together—seeing the same and common operating picture so as to execute tasks without conflicts.
- ✓ Technology to amplify situation awareness is needed to enhance cognition through ubiquitous and seamless visualization.

Observations/ Recommendations:

- There is a need to create BSA with a constellation of intelligent and responsive sensors.
- BSA has to be persistent and pervasive with focus on the adversary targets.
- Critical information needed by the commander must be displayed with less clutter.
- BSA should provide a common operating picture (COP) to commanders and their battle staffs so as to enable shared situational awareness (SA), review, annotate, discuss, adopt important issues relevance to the commander's critical information requirement (CCIR) and be able to maintain continuous review of any spatio-temporal changes in running estimates.

- Humans have specially endowed ability to interpret information and make meanings out of small volume of data; this capability is limited in high intensive, dynamic battlefield systems with different sources of data with multivariate scales.
- There is a requirement for data reduction to scale up to the degree of first-level effects, and information fusion tools for automated inference and understanding of dynamic information that scales up to third or fourth level effects. That is, the commander should be enabled to interpret information during situation changes and under technology degradations.
- There is a need to move information from technology initiated points to field soldiers to improve operational and actionable intelligence.
- Superior situational understanding is a function or good SA. The commanders should have access and means to visualizing battlefield information network so as to establish seamless and dynamic synchronization across services and command echelons. For example, SA models should allow for context-based, time-shared, rapid assessment of battle asset damage.
- Human-machine interfaces, particularly the visualization capabilities, must be able to be tailored to the role of the users and situational tasks.

Insight 4: In the technology-enabled BCS, the commander is considered to be an adaptive knowledge worker. The commander must stay agile, be informed, be responding to changes in information, and be equipped with mobile SU systems through intelligent sensor-enabled SA. The commander must be able to reason from the first principle of self-awareness in a technology degraded SA environment.

Fundamental Question: What are the characteristics of the commander in the future BCS?

Discussion

- ✓ The commander is the information consumer and a knowledge worker in the future technology-enabled BCS.
- ✓ The mental models of the commander are relevance in building technology tools to support command decisions.
- ✓ Technology should support the commander's conscious and thoughtful reaction to situations; for example, generating prospective plans when a situation changes.
- ✓ Technology should allow the commanders to adapt to new situations-- learn new things, interact with new behaviors, etc.
- ✓ Technology should tie the field commanders and the soldiers into a common information bridge, allows for collaborative decision making process, and relax bureaucracy while retaining the parochial hierarchy in the military organization.
- ✓ The commander's role is, in addition of being an intuitive statistician, will also be a knowledge manager. Must acquire the ability to do sensemaking through quick time pattern recognition and pedigree information fusion beyond the second level effect.

Observations/ Recommendations:

- Technology enabled commander's decision must consider human and technology capabilities through task assignment methods (LTG Richard Keller). A capability matrix for task allocation is an essential cognitive model for this purpose.
- Commanders should communicate, collaborate and monitor joint/combined operations in a highly decentralized environment. The German concept of Auftragstaktik, in which subordinate leaders acted independently as a result of clear understanding of the intent of commanders, has all the characteristics and success stories to be introduced into network-centric C2.
- Commanders should be able to make decisions in a volatile, uncertain, complex, and ambiguous battle environment with flexible technology support. Examples of such supports include, sharing command intents, shared SA, ability to synchronize decision processes and view running estimates in real-time.
- Technology should help the commander to rapidly achieve coherent and decisive effects.
- Technology should enable the commanders to maintain unity of command within a joint/combined force and unity of effort with coalition partners.

Insight 5: The commander and the battle staffs will need intelligent decision support systems (DSSs) that can help them to envision, predict, and anticipate future states of a battle space—events, adversaries, inter-agency and intra-agency operators, and so on. Such DSSs must be able to use symbolic information as an input. This can be in the form of graphics, episodic, and echoic waveforms which can be transformed into seamless information coding schemes for display and visualization models.

Fundamental Question: What are the features of the commander's decision support tools in BCS?

Discussion

- ✓ Intelligent decision support systems are needed to provide the commanders and battle staffs with models for creative applications of human experience, knowledge, and intuition using battlefield information dynamics.
- ✓ DSS to amplify human cognitive edge.
- ✓ Commanders require and need capabilities to enable decision superiority in a fast tempo, constrained and dynamic battle systems with changing adversary characteristics.
- ✓ Commanders need tools to help them to construct more efficient plans with rich information superiority, while allowing for enhanced spatio-temporal cognitive understanding of the battle situation through a well designed SA.
- ✓ Commanders need tools which can recognize plan failures (since plans rarely map into the adversary battle space in time), predict failure consequences, self-repair failed plans, and provide recommendation with levels of acceptable confidence.
- ✓ Commanders need tools that are easy to interact and collaborate with machines.
- ✓ Commanders need tools that estimate the adversary's mind with plan estimates to counter the adversary's intent.

Observations/Recommendations:

- Decision support tools should be developed with a diverse use of human expertise—people see the same problem with different lenses and construct different hypotheses to contextualize the problem; the experienced commander develops a repertoire of constructs, algorithms, and principles to explain every situation that may arise.
- The tools should be able to reason in contextual and situational problems with different scales, risks, and uncertainties.
- The tools should have decision-centric interfaces to capture individual decision making styles; recognize Personal Construct Theory (PCT) since the world is perceived by a person in terms of whatever meaning that person applies to a situation. Variations occur at different levels of information abstraction (sensemaking) and situation understanding.
    - Adaptive, content-sharable, and consistent human-machine interface (HMI).
    - Ubiquitous support for knowledge management.

    - Human essential information network capability: information exchange capability through video, voice, graphics, texts, signs and gestures, and so on.
    - HMI functionalities tailored to optimally use different human modalities of information and communication processing.
    - Provides pervasive document processing capability, including, text mining and interpretation, processing of dynamic video streams for digitally shared tactical pictures, mix mode interchange of information modalities; e.g., converting video streaming into texts, textual messaging into graphic forms or sound.
    - HMI with access to authenticated users, context free query, and support for biometric information of authorized users.
- Integrate human and machine capabilities for hypotheses management—balancing machine capability for handling numerical scale problems with human ability for intuition.
- Provide decision and planning support capabilities that cover commander functions and roles. These include, e.g., commander's intent, commander's critical information requirements (CCIR), and planning guidance.
    - Automated support for running estimates based on contexts.
    - Seamless generation and sharing of plans, orders and PIR.
    - Provide bridges and platforms for real-time collaboration, coordination, and enactment of changes before, during, and after technology glitches.
- Tools to give timely updates on the adversary intelligence organizations, assessments, estimates, and other intelligence products to support the commander's decision-making process; this includes the adversary courses of action.
    - Help to establish new sensemaking process under evolving PIRs.
    - Help to maintain and update CCIRs as situation changes.
    - Help to analyze the relative combat power of an agile, moving, sophisticated enemy with its support network of latent coalition.
    - Help to nominate high pay-off target lists as situation changes.
- Promote active use of semiotics to enhance information visualization techniques in the decision tools, including multimodal platforms: video, graphics, symbols, etc. This should be achieved both at the input and output phases of information management process.
- Create tools that can help the commanders to know what they did not know before, and avoid creating tools which are only duplications of the commander's mental models. Such tools should be able to reason spatially, temporally, retrospectively, prospectively, and with ability to anticipate the adversary intents and courses of actions.
    - Create ad hoc cognitive tools that are reconfigurable, adaptable, and ready for plug and play into situation foxholes.
    - Create cognitive tools that can explore frontiers of artificial ignorance; i.e., explore decision making space and regime to identify contextual information that the commander does not currently know and their impacts on command decision making.
- Requirements for near real-time reduction of uncertainties imply extensive use of automated inferential support tools.

Insight 6: Future battle commanders must be ambidextrous leaders. The commanders, at different times and space, must be capable of changing, adapting, learning, and leading a team in battle environments with changing information characteristics and footprints.

Fundamental Question: What are the characteristics of command leadership in the future BCS?

Discussion

- ✓ Modern battlefields with their adversaries are dynamic, evolving, and changes in concepts of war doctrines and operations.
- ✓ The commander as an adaptive living system agent should be responsive to battlefield information changes.
- ✓ Commanders must be cognizant of cultural awareness since modern wars are fought through "coalition of the willing" and joint services between and within nations.
- ✓ Commanders must be able to understand the changing enemy characteristics and intents, and adapt his/her strategy to counter that of the enemy with measurable effects.

Observations / Recommendations

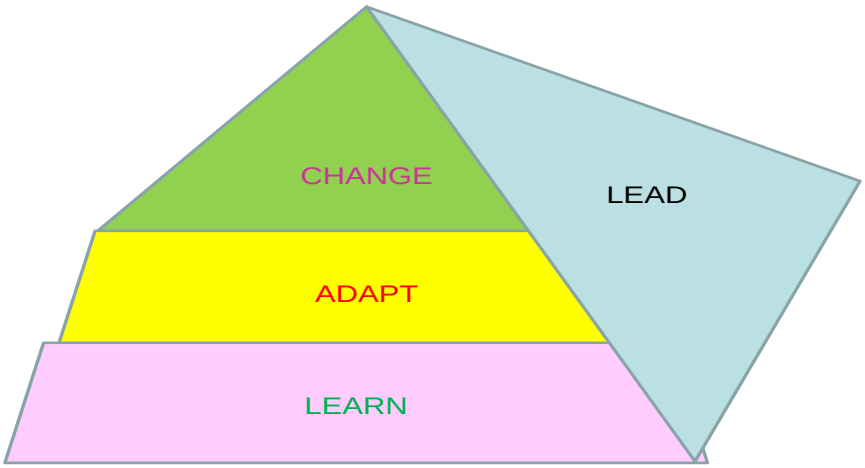
- Commanders must be trained to acquire flexible critical thinking skills.
- Commanders must be cognizant of battlefield changing viewpoints and evolving adversary strategies.
- Commanders and the field soldiers should be trained to use and adapt to technology degradation and make decisions that are inherently tacit, but relevant to the context of tasks.
- The commanders must be trained to acquire the relevant analytic mind-set so as to deal with complexity of battle space dynamics and organizational changes.
- The commanders should be trained to acquire the worldly mind-set so as to adapt to and work with many influences of cultural dynamics such as coalition standard procedures, command hierarchies, and jointly-enabled effect based operations.
- The commander should acquire collaborative or social mind-set and use it to enable joint actions in different settings.
- Human factor experiments are needed to test how commanders envision adversary behaviors and their intents in dynamic battlefield systems.
- Human factors experiments are needed to test the commander's flexibility and agility in employing both short- and long-term memory in pattern recognition tasks, causality analysis, and enactment of retrospective knowledge to chaotic battle contexts like stability and security operations (SASO).

- Human factors experiments are needed to evaluate and validate situation understanding models used by commanders. For example, the flexibility in constructing running estimate models to identify critical adaptive opportunities within a cycle of operation.

Insight 7: Training and education of the future commanders need to be centered on technology pedagogy while emphasizing professional self- and group- developments and experiential training. The training and education courses should be packaged to be rapidly adaptable and portable similar to intelligent ad-hoc network systems. The commanders and the battle staffs must have access to education and training opportunities anywhere, any time by using technology platforms that can integrate and use COT (Commercial Of the Shell Technology).

<u>Fundamental Question:</u> In the information-dominated operational environment, have we adequately prepared our current and emerging battle commanders to be cognitively ready?

Discussion



THE CALL MODEL

- ✓ A new training paradigm is desired; one that incorporates Change, Adaptation, Learning, and Leadership (CALL).
- ✓ Encourage and train for ambidextrous leadership: ability of the commander to envision multiple opportunities and prioritize the ones relevant to problem contexts.
- ✓ Future commanders must possess a "joint and expeditionary" mindset.
- ✓ The commanders must be trained to acquire proficiency in the use of a wide range of new technologies, particularly within the information arena.
- ✓ Commanders should be trained for critical thinking skills and tested for cognitive readiness performance with metrics that can be used to measure abilities to perform

higher order cognitive tasks while reasoning from the first principles and making inferences to predict higher order battle effects.

- ✓ Leadership training should be responsive and adaptive to needs, packaged and delivered to sites at anytime, anywhere; taking into considerations the centrality of commander and dimensions of the adversary and command tasks.

Observations / Recommendations

- Commanders must be trained to acquire flexible critical thinking skills.
- Commanders must be cognizant of battlefield changing viewpoints and evolving adversary strategies.
- Commanders and the field soldiers should be trained to adapt to technology degradation and make independent decisions with less time and risk.
- Training systems should emphasize meta-cognition using knowledge-based models—mental models, cognitive maps, heuristics generated from experiential knowledge, etc.
- Training systems must be tailored to recognize creativity while decoupling individual and group ingenuities from organizational constraints. Thinking outside of the box, such as imagining the impossible scenarios, events, and their consequences should be emphasized.
- Training systems should be pedagogic, tailored to all command levels, with goals that address different levels of task complexities.
- Training systems should consider performance metrics that can evaluate impact of variations in task domains as well as individual capabilities with different levels of technology support and usability.
- Training systems should acquire ecological validity in the field; many soldiers and commanders are trained to use technology with abstract examples; at the field, either the technology is not inserted for battle actions or it is not enough for the field soldiers and their commands.
- Training systems should create opportunities for commanders to cope with complex information and made rapid decisions under fatigue and stress.

Insight 8: Technology in the future BCS must be designed to be minimally uninterruptable, rugged, and resilient so as to be protected against enemy attacks and uncertain failures. The technology platform must be scalable, interoperable, reliable, and trustworthy.

Fundamental Question: What technology characteristics are required to produce a true collaborative, joint human-technology BCS?

Discussion

- ✓ Future BCS will need technologies to provide automated situation and threat awareness capabilities with the ability to distribute SA to teams and individuals on timely bases, and with relevant to the context of information requirements.
- ✓ Future BCS will need technology-enabled tools to enhance human cognition under various task conditions; examples include amplification of human limited memory capacity:
  - (a) echoic or audio memory for hearing and discriminating noise from real signals;
  - (b) iconic or visual memory for detecting semiotic signals and spatial cues;
  - (c) haptic or tactile cues for covert communications.
- ✓ Future BCS will need decision support tools to help commanders and battle staff to make sense of multivariate data.
- ✓ The components of BCS technologies should be modular, easy to maintain, and their functionalities defined and shared across all C2 platforms.
- ✓ The components of BCS technologies should be resilient, rugged, and be self-repairable and configurable if attacked.
- ✓ The components of BCS technologies should be none obstructively interoperable, and the information generated by the system should be scalable enough to support contextual tasks.
- ✓ Resolutions of critical information are sometimes a drawback to the commander's decision making.
- ✓ The fidelity of information generated and analyzed by technology sources must be trustworthy.

Observations / Recommendations

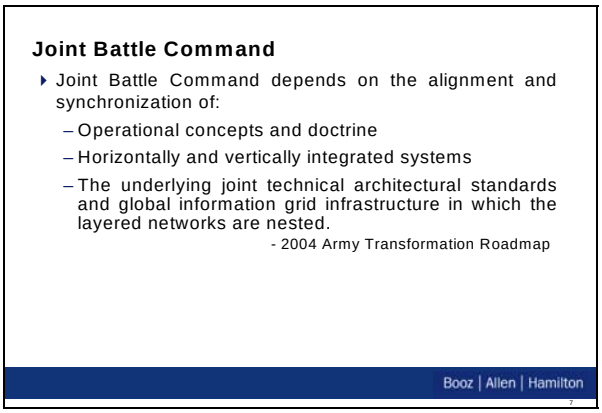
- Emphasize the use of familiar COT (commercial of the shelf technologies).
- Emphasize information availability through asynchronous communications.
- Consider the human factors during technology design: emphasis technology-enabled tools for shared SA, team mental model, and rapid information sharing in a seamless manner.

- Build technologies that can speed transitioning information from awareness state to situation understanding (SU) state.
- The HMI should emphasize:
    - Interfaces that can adapt to the user's cognitive, affective, and behavioral (CAB) states.
    - Usability factors with consistent, free-context, and modality tailored.
    - Interfaces that allow for seamless collaboration across platforms, C2 nodes, and inter and intra organizational services.
- A BCS should have capabilities to automate link procedures to the commander in the field, allowing the battle staffs to see the same information in time and place.
- The SA components of a BCS should be able to provide SA to the dismounted soldier in a way that is least distracting; Here, simple visualization protocols with adaptive interfaces are needed.

Insight 9: Human dimensions in Joint Battle Command (JBC) systems remain problematic. Achieving a human network interoperability requires the understanding of socio-cultural cognition, ecological sensemaking, and the ability to reconcile and scale different standard operating procedures (SOP) into a common metric of doctrinal statements. The operational impacts of socio-cultural and human terrain networks, node-to-node commander's intent with mixed and joint command structures will continue to be a limiting factor in successful JBC operations.

<u>Fundamental Question:</u> What are the components of human dimensions in technology-enabled Joint Battle Command systems?

Discussion



- ✓ Current and future battle will continue to require coalitions, joint services or military, non-government organizations (NGOs), and other civilian entities.
- ✓ JBC is an integrated system of ideas, learned behavior patterns, and many characteristics of different societies—both intra and inter.
- ✓ There is the present of pervasive requirements for cultural cognition.
- ✓ The stakeholders in JBC have their different standard operating procedures, doctrines, mindsets, frameworks, techniques, and methods. They think and feel differently; they perceive risk differently.
- ✓ Jointness is a function of how people interact.
- ✓ JBC is based on a set of assumptions about the stakeholders: beliefs, values, and norms that are shared by organization members. Each dimension can metaphorically represent the spatial location of individuals and group thinking in a trajectory of social norms.
- ✓ Loyalty is centered on the parent organization.
- ✓ Language learning will continue to be a constraint in coalition and/or joint environments using different cultural mixes.

Observations / Recommendations

- Emphasize cultural awareness and train for it; culture influences the cognitive foundation of teamwork---communication, coordination, and decision-making.
- Develop methods and doctrines to capture and reconcile different standard operating procedures.
- Continue to emphasize language learning.

- Develop training methods on how to achieve C2 unity of effort in the absence of direct authority.
- Develop decision support tools to capture cultural schema in a JBC; such a tool should be able to quickly recognize the joint members and create a training schema based on their requirements.

Insight 10: The future battle command (BC) work systems should and must be defined in terms of transformational paradigm shifts in doctrines across all service levels (joint, intra-, lateral, and horizontal) with regard to edge network-centric philosophy. Achieving this requires a new concept of work design known as Intentional Work System (IWS).

<u>Fundamental Question:</u> What is the nature of work system in the future Battle Command systems?

Discussion

- ✓ Current military organizations are based on constructivist theories and mostly hierarchical; People are characterized primarily in terms of their ability to perform physical tasks, with limited attention given to those perceptual and psychomotor skills needed to control machines and processes.
- ✓ Work systems for future BCS should be premised on a cognitivist approach—driven by information management, and anchored on knowledge-based organizations.
- ✓ Recognize that lessons learned are important feedback and major input to adaptive and learning organizations.
- ✓ A BCS can be described by a collaborative work system (CWS); a work system whose domain is a collection of collaborative agents such as human-human, human-technology, or technology-technology entities.
- ✓ A BCS can be described as a complex work system; the term "complex" is added here to emphasize the complex nature of both human-technological interactions and their subsequent emerging, but unpredictable behaviors.
- ✓ Knowledge management will dominate the operation of future BCS and will be premised on intentional work system..
- ✓ Intentional Work System (IWS) defined:
  - ➢ A well-formed intentional work system reflects an ability to handle higher forms of complexity and emergence within a competitive environment. An intentional work system deals with emerging variations of meaning and focus, alternative objectives and means-ends relationships, just-in-time solutions, and a host of other socio-cognitive factors that drive both what and how work is done.
  - ➢ An organized collection of human and technical entities that
    - discern what is important to achieve in a complex and emergent situation;
    - identify pathways, obstacles, and constraints relative to achieving those objectives;
    - create and maintain a coherent understanding of the work capabilities that must be applied within those pathways; and
    - establish a cultural environment for sustained learning and adjustment as the organization and its environment evolve.

Observations / Recommendations

- Knowledge management models should take advantage of the distributed nature of C2; e.g., the commander's intent is cognitively developed and socially distributed, making the product of commander's intent socially constructed into the organizational knowledge base.
- Facets of knowledge management must revolve around the staff level where most of the activities of information management and processes take place.
- Models to optimize individual and team learning processes in acquisition of complex problem solving skills.
- There is a need for prescriptive and descriptive control theoretic models of knowledge management where lessons learned are used to refine the knowledge management output—for actionable intelligence and training.
- The work system model should have the capability to capture the human intent and awareness (tacit knowledge) and share them with others through active visualization models (explicit knowledge).
- The work system should allow team, group, and distributed decision making with platforms for experiments and metrics for performance evaluation; for example, the development and empirical testing of models of individual and team behaviors that can explain deviations between expected and achieved human performance for cognitive tasks (e.g., detection, recognition, categorization, prediction, inference, information search, integration, decision making, team coordination, and resource allocation).
- The tripartite process of knowledge development, application, and refinement must co-exist at equally tripartite levels of information abstractions at the strategic, operational, and tactical levels respectively.
- There is a need for intelligent knowledge bases and decision tools to capture and represent diverse battle space expertise and avoid information overload.

Insight 11: Transitioning into an IWS will require an assumption-based cognitive architecture (ACA) that will explore more studies in high order cognitive (HOC) information processing. High order cognition should be able to remind the decision makers of many expectations in evolving situations by combining multi-level memory and attention resources to gain battle system situation understanding in multiple trait and multiple- interleaving levels of system abstractions that include individual cognitive level, organizational or social level, and ecological level, respectively.

Fundamental Question: If most of the commander's task will be cognitive under BCS, what is the nature and level of cognitive skills desired to enable the commanders to cope with information technology capabilities?

Discussion

- ✓ Cognition that reminds the decision makers of many expectations—combined synoptic and episodic memory information must be recognized and explored.
- ✓ Cognitive edge and technology edge capabilities have to be redefined, matched, and synchronized to achieve real-time information superiority.
- ✓ Human mind and its cognitive processes have limitations in dealing with large scale complexities.
- ✓ Extended cognition is needed for the commander to recognize failures at the edge, improvise shortfalls as battle contexts unfolds and evolves.
- ✓ The high cognition commander is a black box with constituent models that are capable of opportunistic planning and contingency decision making on the move.
- ✓ The high cognition commander is an adaptive information processor who can, by priority of needs, select data and information from any of the human senses, with support from technology, convert the information into useable actionable knowledge, with minimum effort.
- ✓ High order cognition (HOC) allows for interpretative and explanative intelligence:
    - o The commander's mind can be viewed as a complex network of concepts generated from battlefield information, cognitive maps of information structures (episodes, events, time, etc.), and tacit experience.
    - o Exhibiting intelligent behaviors by the commander requires a tremendous amount of knowledge assets, including the ability to recall and adapt important information to contexts in the battlefield.
    - o The commander provides the best plausible explanations to situations through abductive reasoning.

  - The commanders can abduct possible knowledge states—retrospectively, currently, and prospectively.
  - The commander has multiple dynamic mental maps of battle situations which are reproducible when needed with minimum effort. For example, a knowledge map that relates Priority information requirement (PIR) and *Friendly Force Information Requirements (FFIRs) in one axes to actions such as See, Move, Strike) in another.*
  - The commander has a spatio-temporal situation understanding in context. (Situational understanding enables commanders to determine the implications of what is happening and forecast what may happen (FM1 5-0.1, pp.1-18).
- ✓ HOC is about "mining" information in the human mind: visualization and awareness are cognitively embedded to achieve this.

Observations / Recommendations

- The human mind's intuitive process is an irreplaceable determinant of combat success but it must be developed, improved and exercised. According to COL Fuller (Foundations of the Science of War, 1993), imagination is the telescope of our minds, envisioning is the visioning space of action from which anticipatory decisions can be developed. Here lie the three cognitive dimensions of HOC.
- There is a need for models that can excavate micro-level information processing at the neural level. The on-going work on neuroergonomics will be an advantage to studies and understanding of higher order cognition.
- There is a compelling need for a comprehensive extension of existing theories of human factors to study, describe, explain and predict how meta- cognition enables human performance in dynamic, constrained, and fast tempo decision making environments. Such theories should account for:
  (a) Individual and group awareness of situations—dynamic and evolving characteristics of battlefield;
  (b) Individual and group understanding of dynamically evolving situations, able to define and contextualize hypotheses, develop solutions, and scale retrospective knowledge to envision the future states of battle situations.
  (c) Individual and group performance by developing synergistic modes that link ecological variables to perceptual control of human actions, cognition, and the neural mechanisms that control the internal reasoning processes and adaptations.
- Distinction should be made between meta-cognition and HOC. Whereas meta-cognition represents highly developed knowledge-base skills, HOC is a construct that seeks to use the existing human information processing capability to enhance meta-cognition to achieve near autonomy and effortless decision making.
- Provide tools to enable anticipatory cognition for understanding unfolding operational needs in time and space.
- Training creativity and critical thinking:
  - It is important to recognize how creativity evolves and used during complex and chaotic decision situations.

- It is important to recognize proactivity and imagination as the corollaries of creativity. For example training the commander to organize his/her memory information contents for use in predictive (and imagination) modeling or mental simulation for decision making.
- Enhance precision during perceiving and acting tasks, such as mitigated by sensory attention. For example, the explication of neural cognition for rational decision making in environment of uncertainty, incomplete information, and partial truth in intelligence estimates.
- Aid the commander in knowledge representation: The human mind uses different multivariate representations and problem-solving strategies. Which of these representations are best suited to the commander under stress in dynamic environments?
- Understand how cognition is organized and manifested in different task situations and time scales (e.g., cognition measured in seconds, neuronal cognition in milliseconds, molecular level cognition in minutes, and quantum cognition in a fraction of nanoseconds).

Use of Acronyms and Abbreviations

ACA	**Assumption-based cognitive architecture**
ARL	**Army Research Laboratory**
ARO	**Army Research Office**
BA	**Battle awareness**
BSA	**Battle system awareness**
BC	**Battle command**
BCS	**Battle awareness system**
BCSA	**Battle command system architecture**
BOS	**Battle operating system**
CAB	**Cognitive, affective, and behavior**
CALL	**Change, Adapt, Learn, Lead**
C2	**Command & Control**
CCIR	**Commander's critical information requirement**
CoG	**Center of Gravity**
COP	**Common operating picture**
COT	**Commercial Of-the-shell technology**
CWS	**Collaborative work system**
DARPA	**Defense Advance Research Project Agency**
DSS	**Decision support system**
FQ	**Fundamental question**
HDC	**High dimension cognition**
HMI	**Human-Machine Interaction**

HOC	**High order cognition**
HOCS	**High order cognitive skill**
HRED	**Human Research Engineering Directorate**
IWS	**Intentional work system**
JBC	**Joint Battle Command**
NATO	**North Atlantic Treaty Organization**
PIR	**Priority information requirement**
SA	**Situational awareness**
SA	**Situational understanding**
SOP	**Standard operating procedure**